Progress in HTPE Propellants

NDIA 39th Annual Gun & Ammunition/ Missiles & Rocket Conference

April, 2004

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Insensitive HTPE Propellants

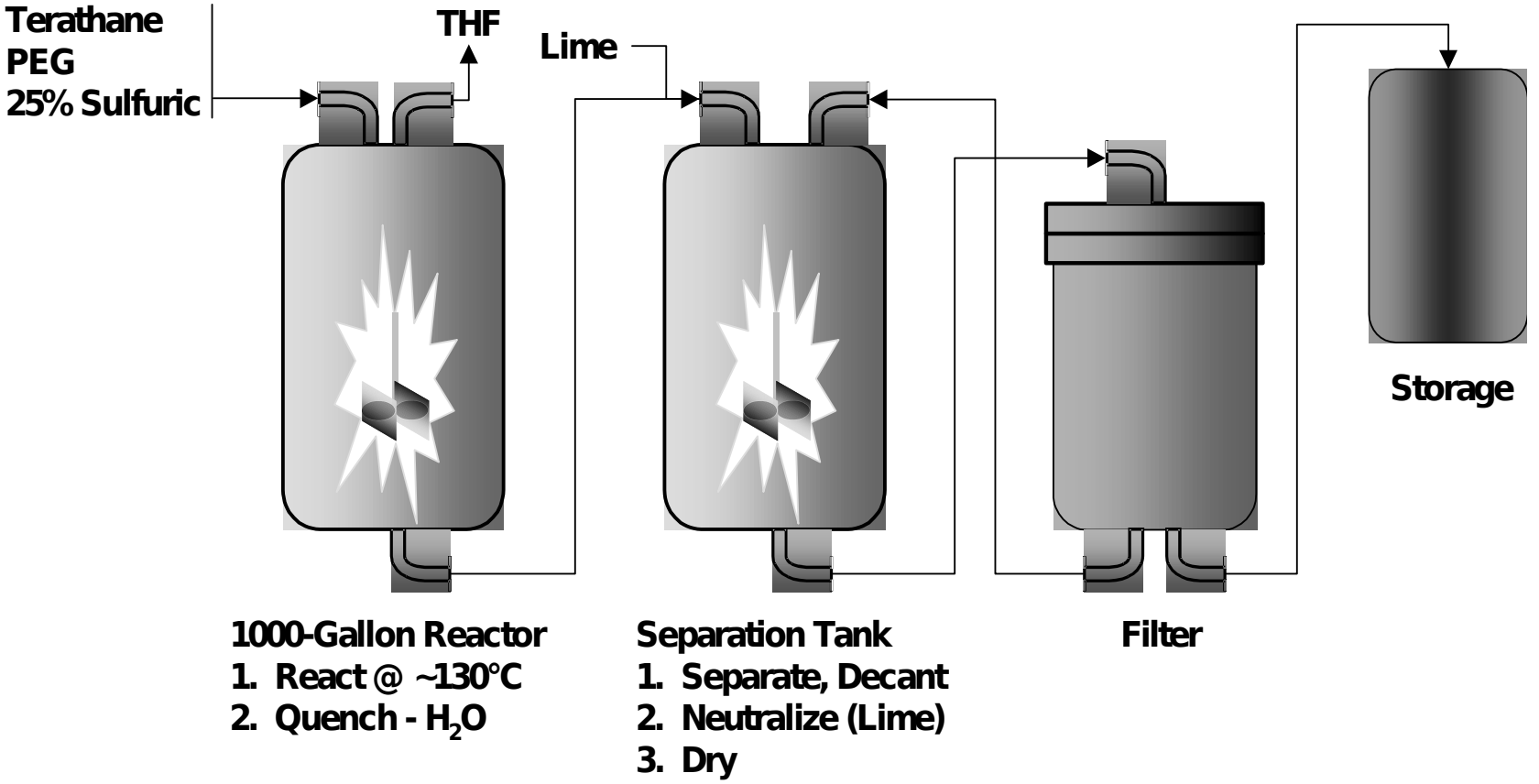
- ***Based on Hydroxy Terminated Polyether (HTPE) Polymer with Ammonium Perchlorate and Ammonium Nitrate Oxidizers***
- ***Both Aluminized and Reduced Smoke Formulations are in Production for Evolved Sea Sparrow Missile***
- ***Under Development or Qualification for Several Other Applications***
- ***Propellants Meet All Requirements for Typical Tactical Applications***
  - Mild IM Responses
  - High Delivered Performance
  - Excellent Mechanical Properties
  - Well Behaved Ballistic Properties

HTPE Polymer is Designated TPEG

- ***TPEG is a Block Copolymer of Poly-1,4-Butanediol (Terathane) and Polyethylene Glycol***
- ***Developed by ATK and Du Pont***
- ***Du Pont Holds the Patent But Does not Manufacture TPEG Due to its Low Anticipated Volume***
  - ATK Licensed the Patent Rights for Use in Munitions
- ***Twelve 1000-lb Batches Manufactured by Subcontractor***
- ***NAVSEA Installed a Facility at ABL to Manufacture TPEG on 2500-3000-lb Batch Scale***

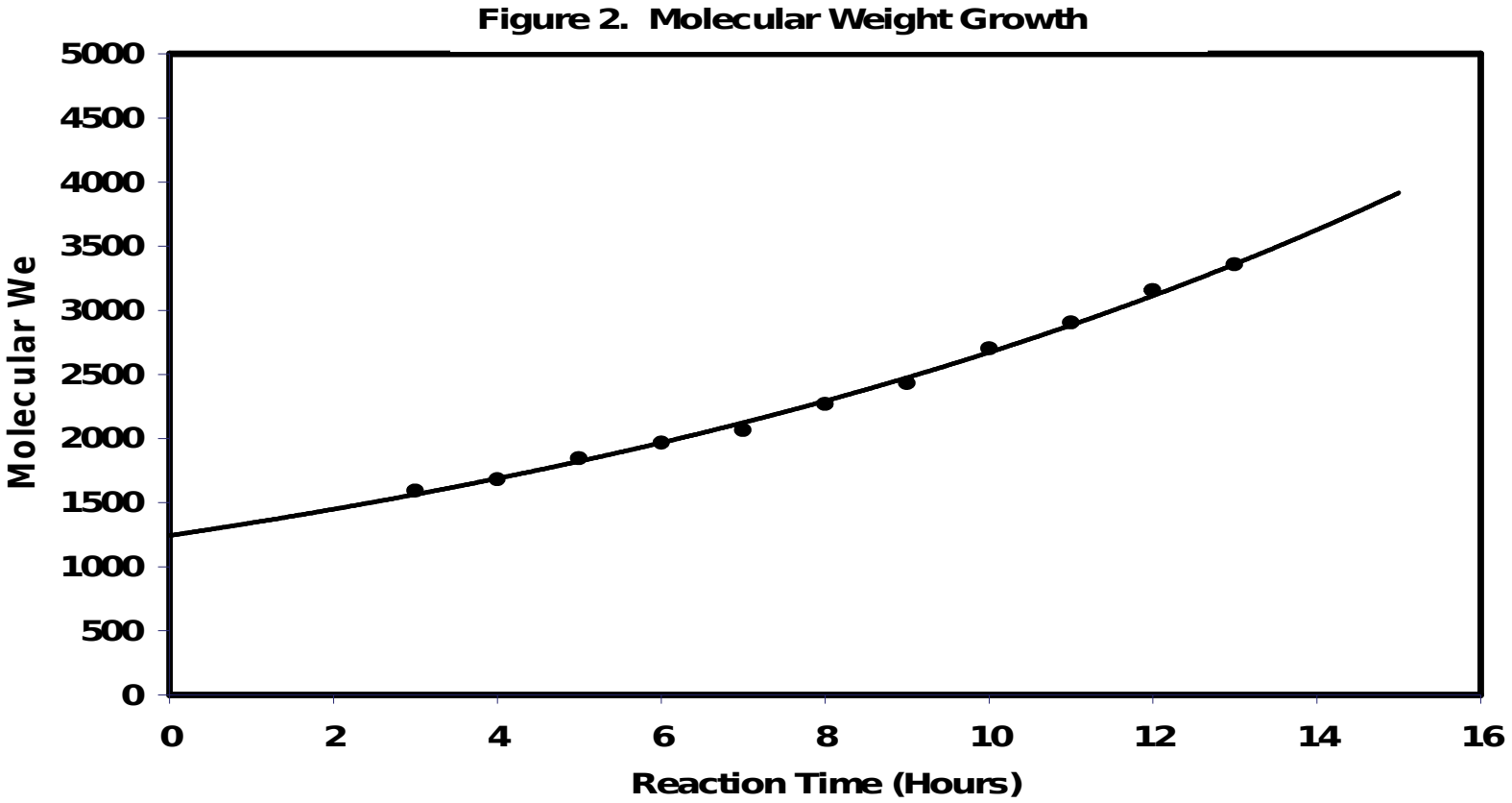
TPEG Plant Description

Figure 1. TPEG Synthesis Flow Diagram



TPEG Manufacture

- ***Reaction is Complete to Desired Molecular Weight in 12-14 Hours***

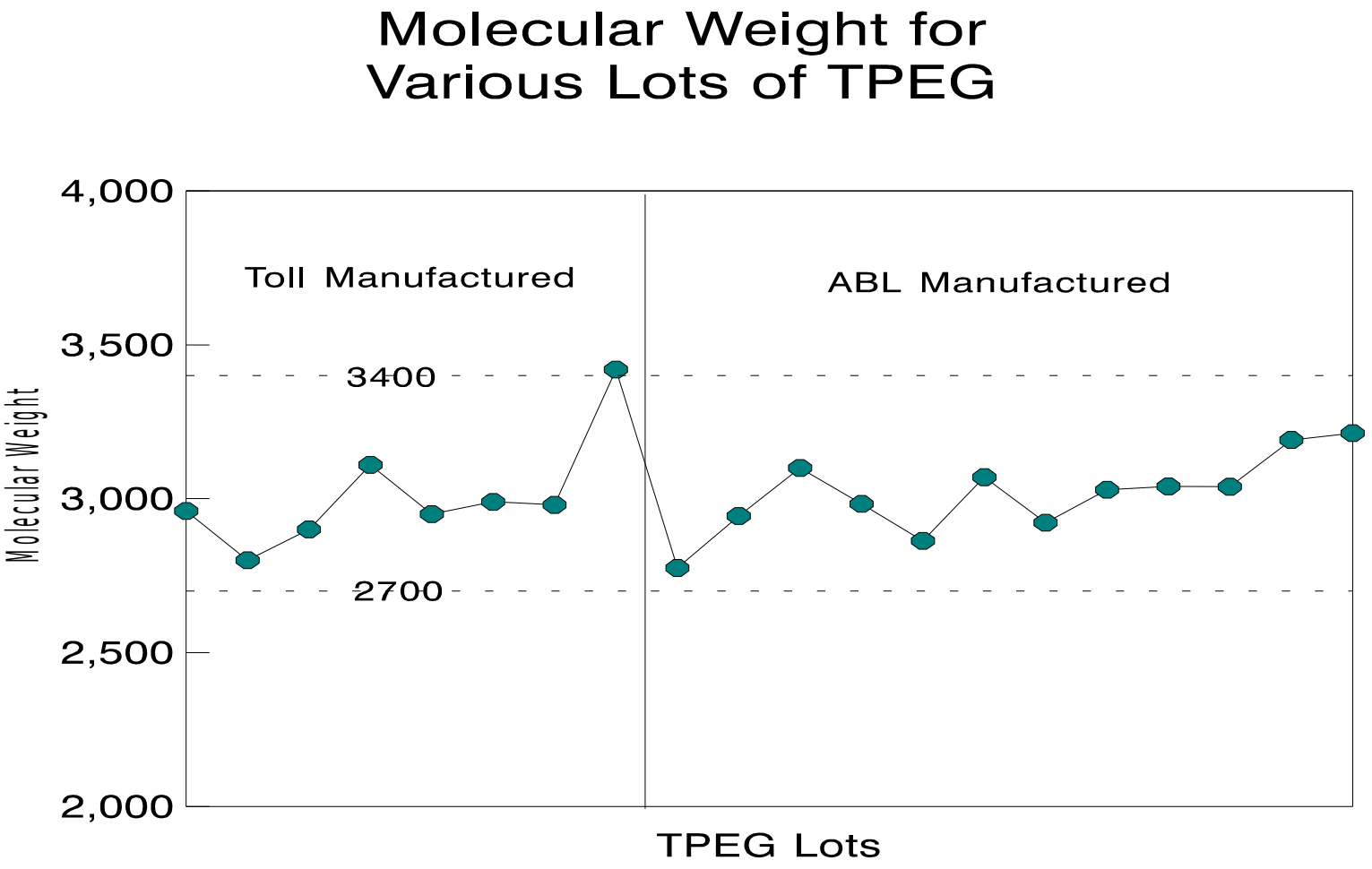


Manufacture of First TPEG Batch

- ***Product was Within Specification and Family in All Measured Parameters***
  - **Analyze for PEG and THF by NMR**
  - **Analyze for Molecular Weight by GPC**
  - **Analyze for BHT Antioxidant by HPLC**

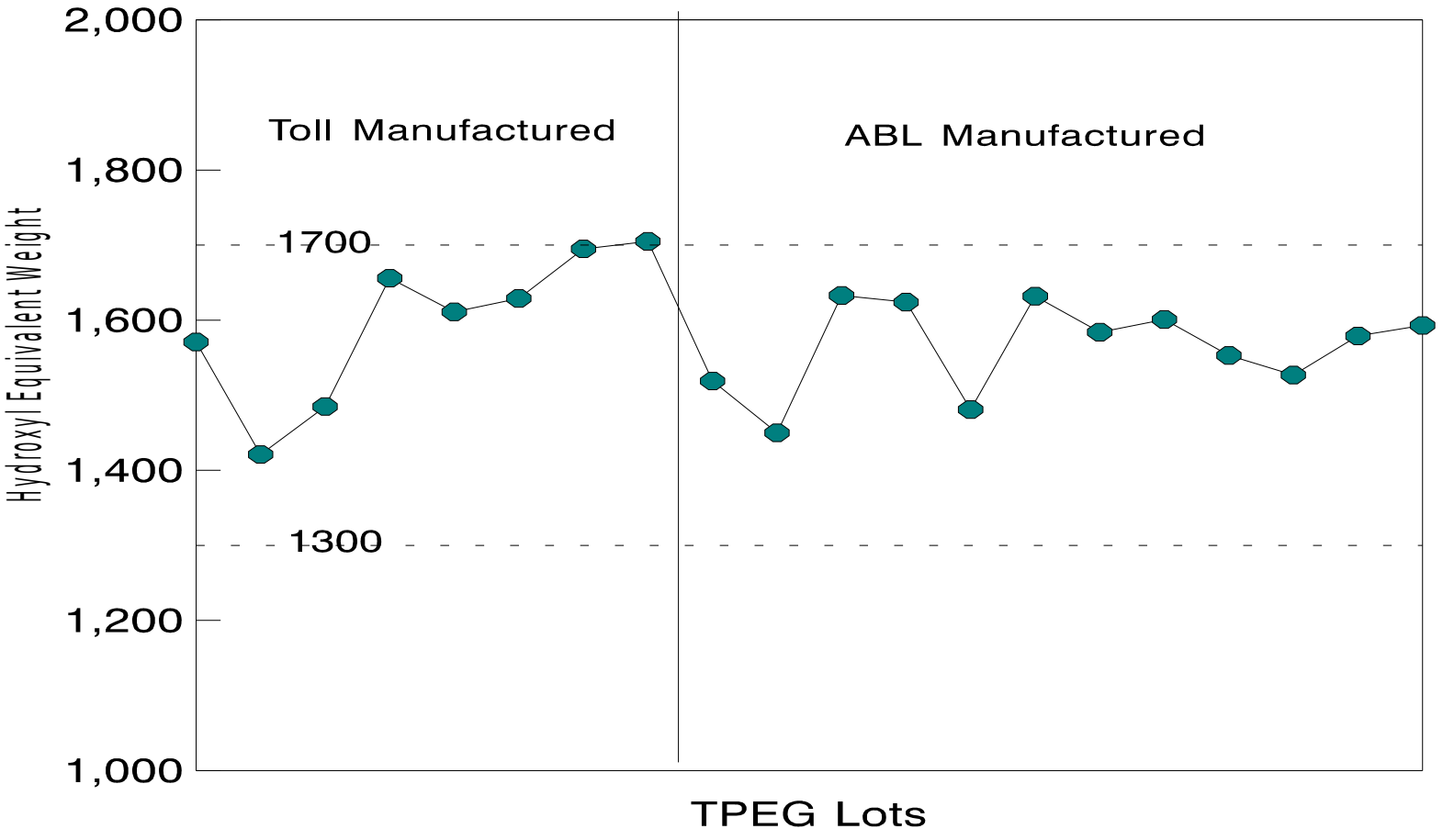
	% PEG	% THF	Molecular Weight	OH Equiv Weight	Viscosity at 120°F, p	BHT, %	Water, %
Spec Max	55	55	3400	1700	15	0.20	0.05
Spec Min	45	45	2700	1300	--	0.05	--
Toll Mfr Avg	51	49	2956	1581	12	0.07	0.03
Toll Mfr Std Dev	3	3	94	97	2	0.02	0.01
ABL Lot 1	47	53	2903	1535	12	0.07	0.03

ATK TPEG Molecular Weight Well Within Spec



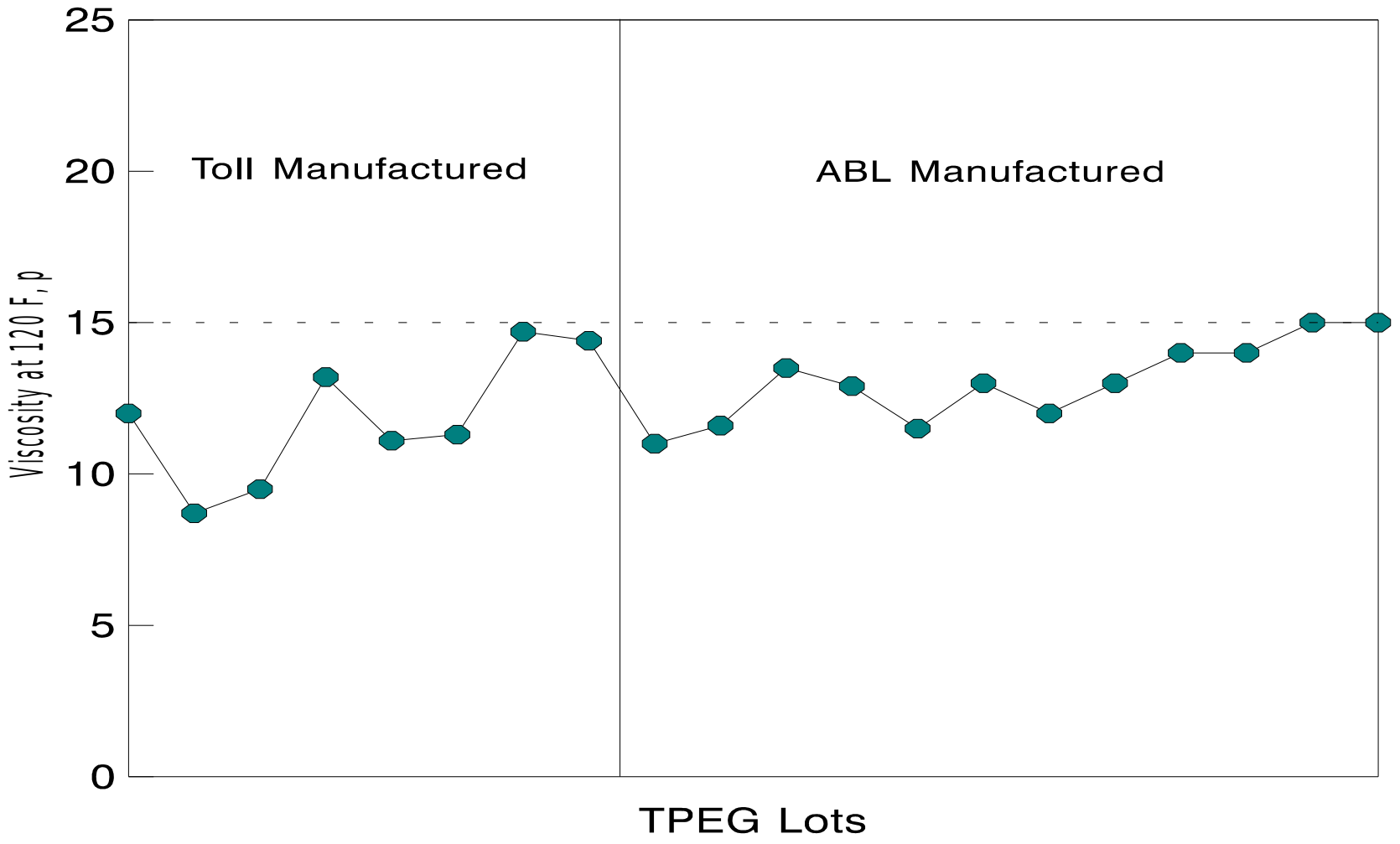
TPEGmw

ATK TPEG Equivalent Weight Well Within Spec



TPEGew0

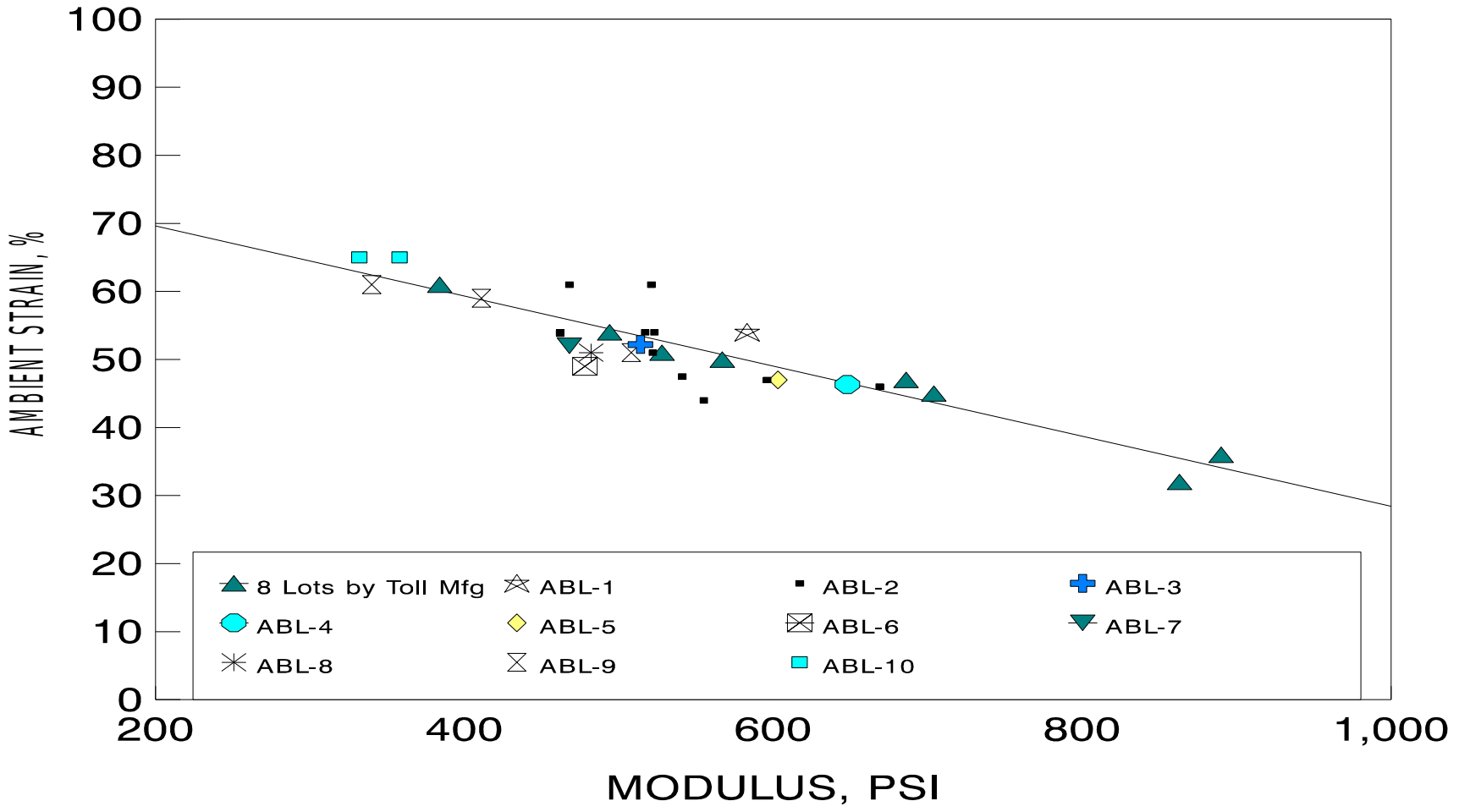
ATK TPEG Viscosity Within Spec



Evaluation of TPEG

in HTPE Propellant

All TPEG Batches Manufactured at ABL Made Good Quality Propellant



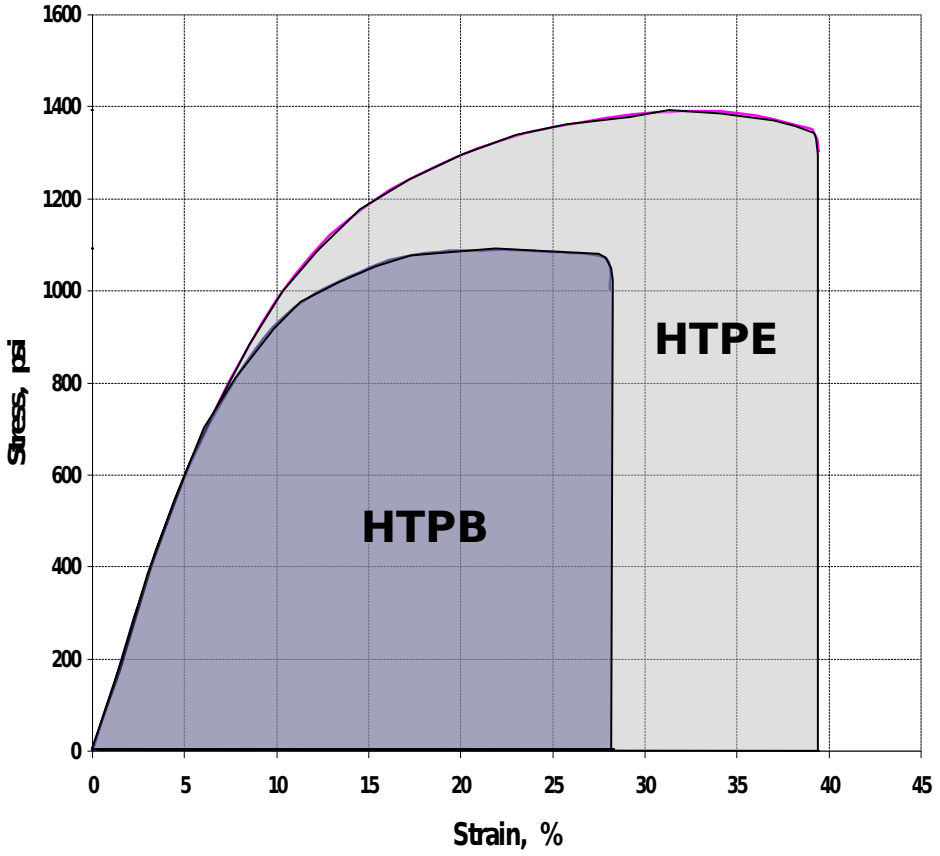
tpegpro0

No Embrittlement Measured in TPEG Propellant

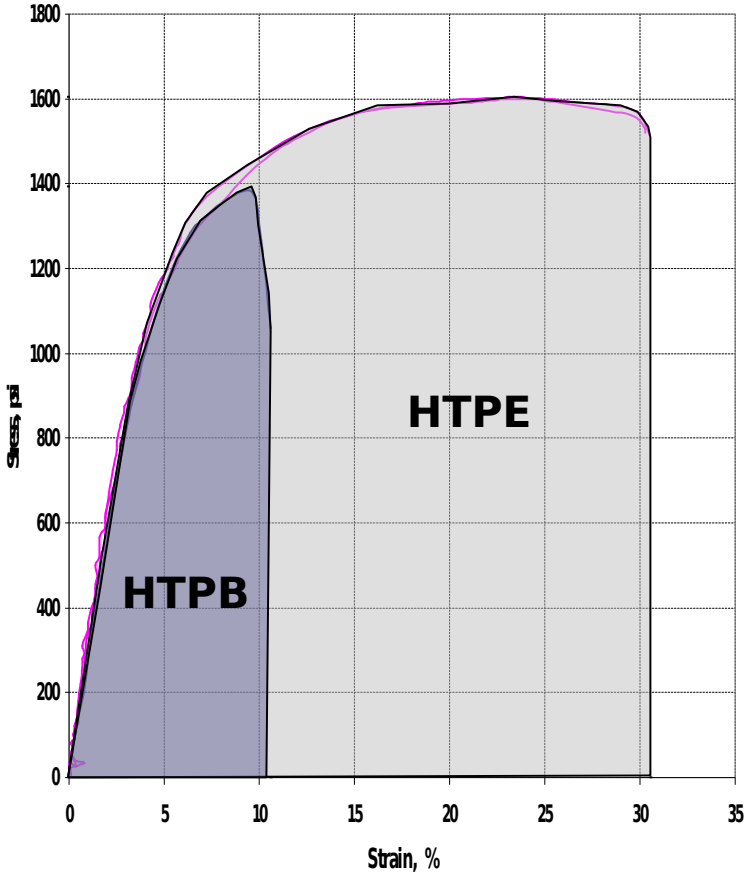
- *Some Propellants Can Embrittle due to Crystallization of the Plasticizer or Polymer*
- *TPEG is a Random Block Co-Polymer Designed to Prevent Crystallization*
- *Neat BuNENA Plasticizer Does Crystallize at About 18°F*
- *BuNENA Does Not Crystallize in HTPE Propellant*

Mix No.	Days After Seeding with BuNENA Crystals	Storage Temp °F	Mechanical Properties at -40°F		
			Stress psi	Failure Strain, %	Modulus, psi
2021	No Seed	Control	306	53	1091
2021	7	-35	360	60	1100
2021	36	-35	317	54	1007
2021	90	-35	320	49	1148
2021	140	-25 to -70	341	61	1198
2025	No Seed	Control	364	62	974
2025	32	-15	312	56	931
2036	60	-15	328	60	1122

HTPE Propellants Have Superior Cold Ignition Strain Compared to HTPB Propellants



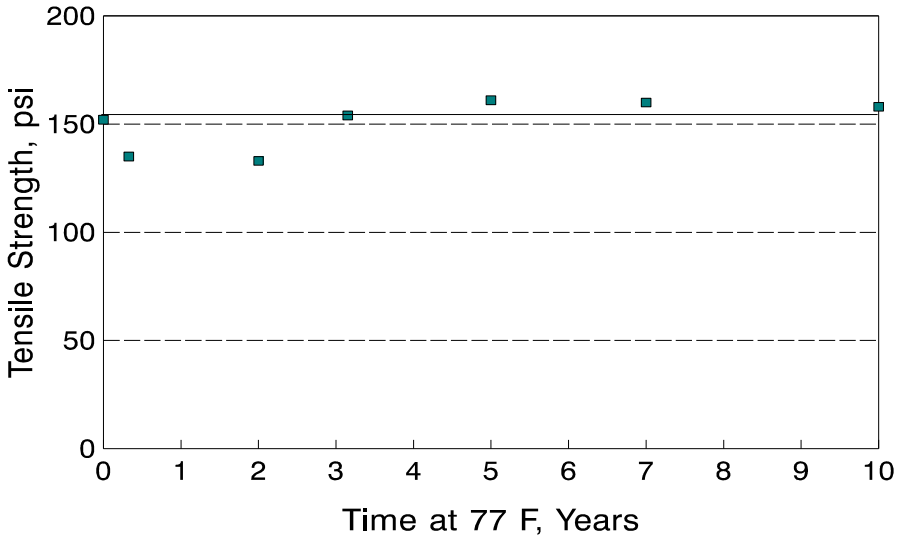
-45 F



-65 F

TPEG Propellants Have Very Stable Tensile Strength and Modulus During Aging

Tensile Strength for HTPE Propellant
Unchanged After Ten Years Storage



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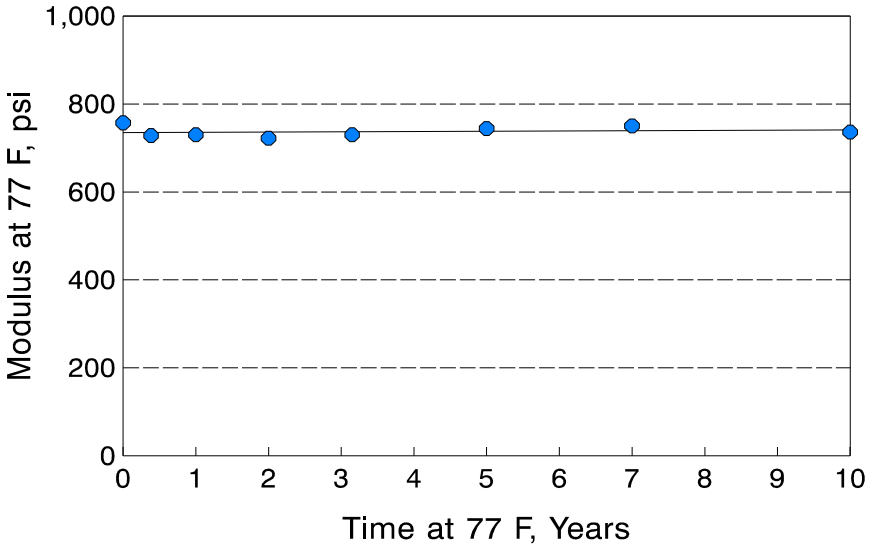
Modulus for HTPE Propellant
Unchanged After Ten Years Storage



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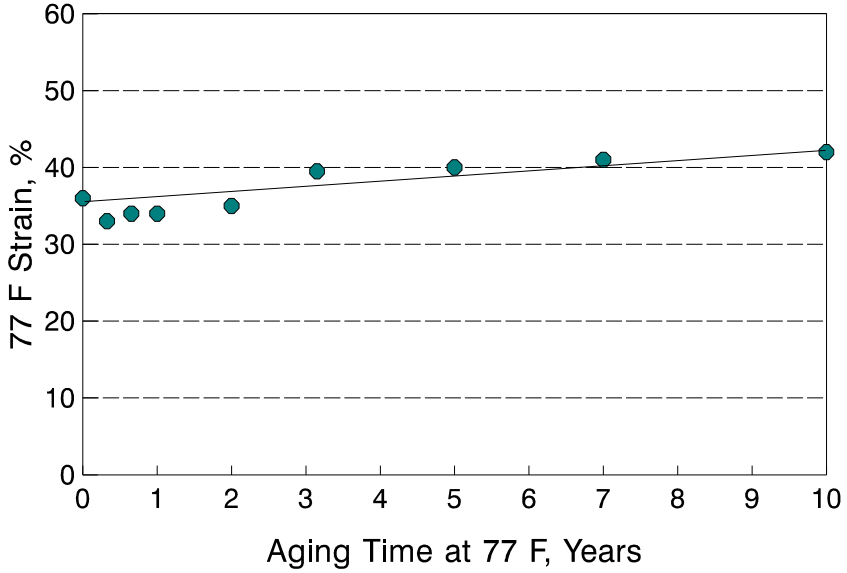
Ambient and Cold Strains Slowly Increase with Time

Strain Allowable for HTPE Propellant Increases Slowly During Ten-Year Storage



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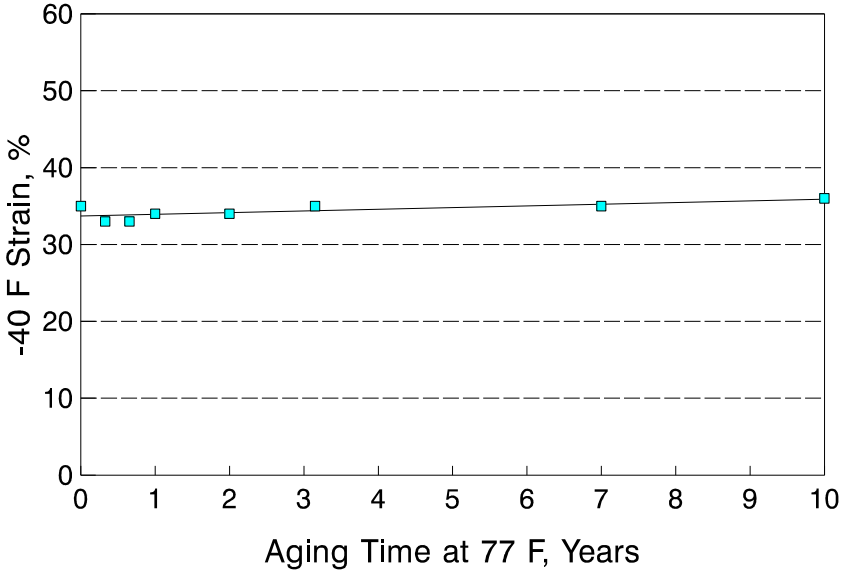
Cold Strain Allowable Increases Slowly During Ten-Year Storage for HTPE Propellant



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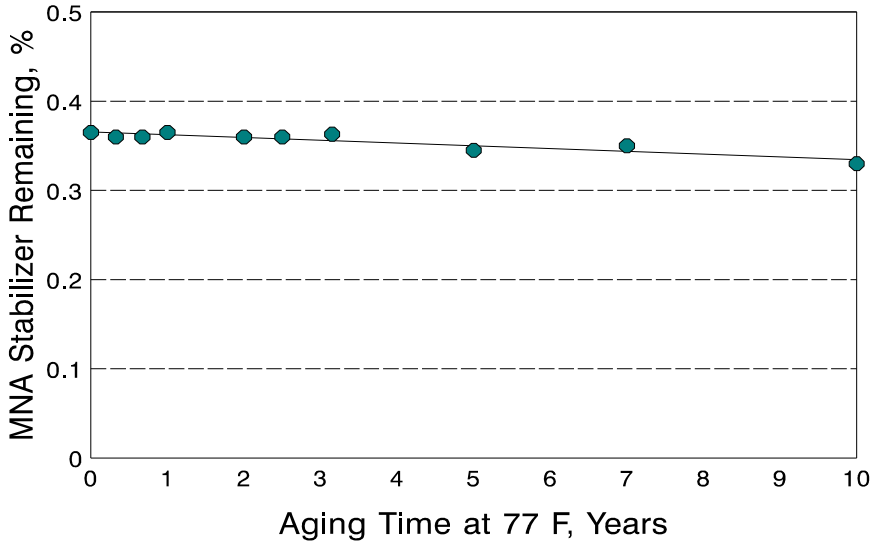
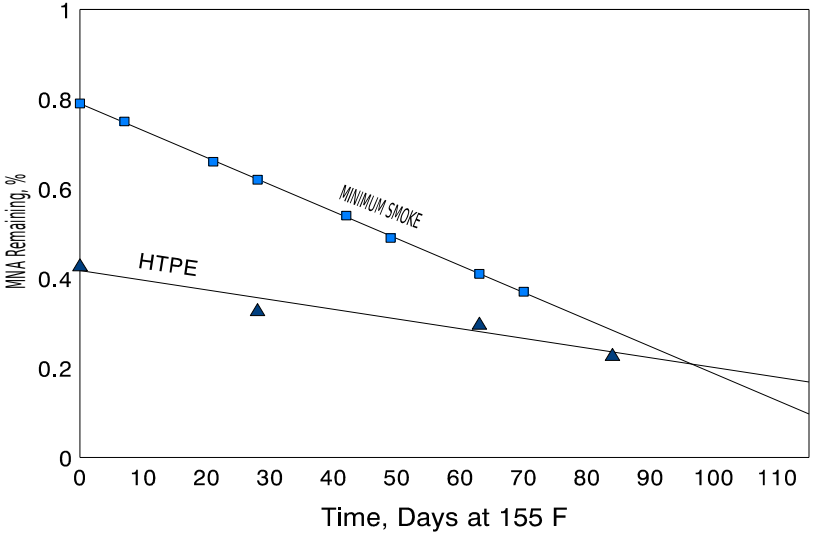
Long Service Life Based on Stabilizer Depletion

MNA Stabilizer Depletion vs. Time During HTPE Propellant Aging



MNA Depletion vs. Time for HTPE and Minimum Smoke Propellants at 155 F



MNA77

REF-25A

- ***MNA Predicted to Deplete to 0.1% in About 90 Years at 77 F***
- ***Service Life Based on MNA Depletion for Accelerated Aging is at Least as Long as for Minimum Smoke Propellants***

Large Scale HTPE Propellant Manufacturing Technology Now in Place at Five Facilities

- ***First 50-Gal Propellant Mix Manufactured at ABL in 1993***
  - Many 50- and 300-Gal Mixes Made Since Then
- ***Technology Transferred to NAWC in China Lake***
  - First 30-Gal and150-Gal Mixes Manufactured in 1995
- ***Technology Transfer to NAMMO in Norway Began in 1995***
  - First 300-Gal Mix Manufactured in 1996. Many 300-Gal Mixes Since Then
- ***Technology Transfer to ATK Plant in Elkton, MD, Began in 2001***
  - First 300-Gal Mix Manufactured in 2002. Several 300-Gal Mixes Since Then
- ***Technology Transfer to IHI Aerospace (IA) in Japan Began in 2003***
  - First 1200L Mix Manufactured in 2003

Steps Carried Out in HTPE Propellant Technology Transfer to IHI Aerospace (IA)

- *Visit by IA/NOF Personnel to ABL to Review Technical Manuals*
- *Ingredients Shipped to IA/NOF*
- *Visit by ABL Personnel to IA/NOF to Inspect Facilities*
- *Visit by IA/NOF Personnel to ABL to Witness 1-Gal Propellant Mix*
- *Visit by ABL Personnel to IA/NOF to Witness 10L Propellant Mixes*
- *Visit by IA/NOF Personnel to ABL to Witness 5-Gal Propellant Mix*
- *Visit by ABL Personnel to IA/NOF to Witness 50L Propellant Mixes*
- *Visit by IA/NOF Personnel to ABL to Witness 300-Gal Propellant Mix*
- *Visit by ABL Personnel to IA/NOF to Witness 1200L Propellant Mix*
- *All Mixes Manufactured at IA/NOF Had Good Properties*

Summary and Future Work

- ***TPEG Plant Installed at ATK/ABL***
  - Capacity of 300,000 to 450,000 lbs/ year
- ***First Twelve Lots of TPEG Manufactured at ABL Met all Specification Requirements***
  - Good Quality HTPE Propellant Made from Each TPEG Lot
- ***Excellent Low Temperature Mechanical Properties Obtained on HTPE Propellant Made with ABL TPEG***
  - Superior to HTPB Propellant Cold Strain Capability
- ***Excellent Aging of HTPE Propellants Made with TPEG***
- ***HTPE Propellant Manufacturing Technology in Place at Five Facilities***